STATE COLLEGE OF WASHINGTON
AGRICULTURAL EXPERIMENT STATION
Pullman, Washington

Western Washington Experiment Station and
the Division of Agronomy, Soils Section
cooperating

Boron Deficiency Of Alfalfa In Western Washington

by

Karl Baur, Glenn A. Huber, and L. C. Wheeting

Bulletin No. 396

February, 1941

BOARD OF REGENTS

B. A. Perham, President ..... Yakima
C. W. Orton, Vice President and Treasurer ..... Sumner
S. A. Kimbrough ..... Spokane
A. W. Davis ..... Spokane
E. O. Holland ..... President of the College, Secretary, ex-officio

EXPERIMENT STATION STAFF

E. O. Holland, Ph.D., President
Wm. C. Kruegel, B.A., Treasurer

Edward C. Johnson, M.A., Director
E. V. Ellington, B.S., Vice Director

Agricultural Engineering

L. J. Smith, M.E., Agricultural Engineer in Charge.
H. G. Nickle, B.S., Assoc. Irrigation Engineer, Prosser, U.S.D.A.[2]
J. Roberts, M.S., Investigator, Farm Electricity.[1]

Agronomy

E. G. Schafer, M.S., Agronomist in Charge.
O. E. Barbee, M.S., Assistant in Farm Crops.
E. F. Gaines, D.Sc., Cerealist.[2]
W. A. Harvey, M.S., Assistant in Farm Crops.
Harley D. Jacquot, B.S., Assistant in Farm Crops.
L. T. Kardos, Ph.D., Assistant in Soils.
E. J. Kreizinger, M.S., Assistant in Farm Crops.
Carl A. Larson, Ph.D., Specialist in Irrigation Investigations, Prosser.[2]
C. Emil Nelson, M.S., Asst. in Soils, Prosser.
H. P. Singleton, M.S., Associate in Agronomy, Prosser.
D. C. Smith, Ph.D., Assoc. Geneticist, U.S.D.A.
C. O. Stanberry, B.S., Assit. in Soils.
S. P. Swenson., Assoc. Geneticist.
S. C. Vandecaveye, Ph.D., Soil Scientist.
Orville A. Vogel, Ph.D., Asst. Agronomist, U.S.D.A.[2]
L. C. Wheeting, Ph.D., Research Prof. in Soils.

Animal Husbandry

Howard Hackedorn, B.S., Animal Husbandman in Charge.
Hector G. McDonald, M.S., Assistant in Animal Husbandry.
F. G. Meade, B.S., Research Asst. in Animal Husbandry.
Jerry Sotola, M.S., Assoc. Animal Husbandman.

Chemistry

J. L. St. John, Ph.D., Chemist in Charge.
C. W. Eddy, M.S., Asst. Chem. U.S.D.A.[2]
Herman Fallscheer, M.S., Assistant Chemist, Wenatchee.
Kermit Groves, Ph.D., Assistant Chemist.
M. C. Midgley, B.S., Assistant State Chemist.
A. M. Neubert, M.S., Asst. Chemist.[2]
M. Rhian, M.S., Assistant Chemist.
M. K. Veldhuis, Ph.D., Chemist, U.S.D.A.[2]

Dairy Husbandry

E. V. Ellington, B.S., Dairy Husbandman in Charge.
U. S. Ashworth, Ph.D., Research Dairy Chemist.
H. A. Bendixen, Ph.D., Associate Dairy Husbandman.
N. S. Golding, Ph.D., Associate Dairy Husbandman.
H. Harland, Research Assistant.[4]
J. C. Knott, M.S., Assoc. Dairy Husbandman.
C. C. Prouty, M.S., Associate Dairy Bacteriologist.
F. Wolberg, M.S.,[2] Asst. Dairy Husbandman, (P. O. Puyallup).

Entomology & Zoology

R. L. Webster, Ph.D., Entomologist in Charge.
H. H. Dodge, B.S., Res. Asst. in Entomology.
R. D. Eichmann, M.S., Asst. Entomologist.
William J. O'Neill, B.S., Assistant Entomologist, Wenatchee.

Soil Conservation Experment Station[2]

Glenn M. Horner, Ph.D., Superintendent.
L. M. Naffziger, Engineering Aide.
O. A. Leonard, Coop. Agent.

Farm Management & Agricultural Economics

Ben H. Pubols, M.A., Agricultural Economist in Charge.
M. T. Buchanan, Ph.D., Asst. Agric. Economist.
E. F. Dummeier, Ph.D., Agric. Economist.
W. U. Fuhriman, Ph.D., Agric. Economist, U.S.D.A.[2]
W. McMartin, M.S., Asst. in Farm Mgt. and Agr. Econ.
Alden E. Orr, M.S., Asst. Agric. Economist.
W. W. Rufener, M.S., Asst. in Agr. Economics.

Home Economics

Velma Phillips, Ph.D., Home Economist in Charge.
Mildred M. Boggs, M.S., Research Specialist in Home Economics.
Jennie A. McIntosh, Ph.D., Nutr. Chem.
E. N. Todhunter, Ph.D., Associate Professor of Nutrition.

Horticulture

E. L. Overholser, Ph.D., Horticulturist in Charge.
W. J. Clore, B.S., Asst. Horticulturist and Horticulturist, Prosser.
O. M. Morris, M.S., Horticulturist.
F. L. Overley, M.S., Associate in Horticulture, Wenatchee.
C. D. Schwartze, Ph.D., Asst. Horticulturist, and Horticulturist, Puyallup.
C. L. Vincent, Ph.D., Assoc. Horticulturist.
S. E. Wadsworth, B.S,, Floriculturist.

Plant Pathology

F. D. Heald, Ph.D., Plant Pathologist in Charge.
Leo Campbell, Ph.D., Research Asst. in Plant Pathology.
George W. Fischer, Ph.D., Assoc. Pathologist, U.S.D.A.[2]
C. S. Holton, Ph.D., Assoc. Pathologist, U.S. D.A.[2]
Leon K. Jones, Ph.D., Assoc. Plant Pathologist.

Poultry Husbandry

J. S. Carver, B.S., Poultry Husbandman in Charge.
R. J. Evans, Ph.D., Assistant Poultryman.
E. I. Robertson, M.S., Asst. Poultry Husbandman.

Rural Sociology

Paul H. Landis, Ph.D., Rural Sociologist in Charge.
C. F. Reuss, Ph.D., Asst. Rural Sociologist.

Veterinary Science

E. E. Wegner, D.V.S., Veterinarian in Charge.
J. W. Kalkus, D.V.S., Veterinarian, Western Wash. Exp. Sta., Puyallup.
Ernest C. McCulloch, Ph.D., Research Veterinarian.
L. G. Nicholson, D.V.M., Assistant Veterinarian.

Branch Stations

D. J. Crowley, B.S., Specialist in Cranberry Investigations, Cranberry-Blueberry Laboratory, Long Beach.
Harley D. Jacquot, B.S., Superintendent, Adams Branch Station, Lind.
H. P. Singleton, M.S., Superintendent, Irrigation Branch Station, Prosser.
F. L. Overley, M.S., Superintendent, Tree Fruit Branch Station, Wenatchee.

---

[1] In cooperation with the State Committee on the Relation of Electricity to Agriculture.
[2] In cooperation with the United States Department of Agriculture.
[3] On leave.
[4] In cooperation with Washington State Dairy Products Commission.

WESTERN WASHINGTON EXPERIMENT STATION STAFF

(Located at Puyallup, Washington)

J. W. Kalkus, D.V.S., Superintendent.

Maynard S. Grunder, M.S., Agronomist.

Vernon L. Miller, Chemist.

Floyd B. Wolberg, M.S., Dairy Husbandman, West. Wash. Expt. Sta.; Asst. Dairy Husbandman, Wash. Expt. Sta.; and Agent in Dairying, U.S.D.A.

E. P. Breakey, Ph.D., Entomologist.

C. D. Schwartze, Ph.D., Horticulturist, Assistant Horticulturist, Wash. Expt. Station.

Clare H. Rundle, M.S., Assistant Horticulturist.

Glenn A. Huber, Ph.D., Plant Pathologist.

Leo J. Campbell, Ph.D., Assistant Plant Pathologist, West. Wash. Expt. Sta.; Research Asst. in Plant Pathology, Wash. Expt. Station.

Karl Baur, M.S., Asst. Plant Pathologist and Asst. in Soils.

Gordon E. Bearse, B.S., Poultryman.

Cecil F. McClary, M.S., Assistant Poultryman.

C. M. Hamilton, D.V.M., Veterinarian.

William M. Dungan, D.V.M., Asst. Veterinarian.

Verne E. Smith, Laboratory Asst. in Veterinary Science.

Beulah D. Rawson, Secretary to the Superintendent.

TABLE OF CONTENTS

Boron Deficiency of Alfalfa in Western Washington

Karl Baur, Glenn A. Huber, and L. C. Wheeting[1]

INTRODUCTION

The acreage of alfalfa in western Washington has increased rapidly during the past decade. Available information shows that 8,108 acres were planted to alfalfa in 1930, 11,288 in 1935, and 15,920 in 1940. The number of acres of alfalfa by counties are presented in Table 1.

Table 1. Alfalfa Acreage Western Washington Counties*

County	1930	1935	1940
Clallam	2,522	3,339	3,339†
Clark	701	1,375	2,500
Cowlitz	79	77	450
Grays Harbor	7	16	15
Island	239	610	1,200
Jefferson	158	360	525
King	345	346	400
Kitsap	53	34	30
Lewis	622	704	735
Mason	6	17	17
Pacific	1	1	15
Pierce	159	77	189
San Juan	262	693	1,000
Skagit	240	780	1,000
Skamania	180	263	1,060
Snohomish	193	615	1,300
Thurston	31	66	360
Wahkiakum	10	15	35
Whatcom	1,300	1,900	1,750

*Data from census, county agents, and Agricultural Adjustment Administration.
†No 1940 data obtained.

Alfalfa is a cheap source of protein, so necessary to animal feeding, and should hold a more prominent place in western Washington agriculture. The great demand for forage crops is indicated by the 1935 census which shows that 330,000 acres, or 43 per cent of the total crop land in western Washington, was at that time planted to hay crops.[2] In addition to the forage now produced locally, large quantities of alfalfa hay are imported from eastern Washington and out-of-state sections to supply present demands. It is generally conceded that

[1] The assistance rendered by the Works Progress Administration on certain phases of this project is gratefully acknowledged.

[2] Maynard S. Grunder, "Hay Crops for Western Washington," West. Wash. Expt. Sta. Mimeo. Cir. No. 99, May, 1940.

on land suited to the production of alfalfa this crop will out-yield most of the grass or grass-legume mixtures. This is particularly true in Clark and Island counties, in parts of Clallam county, and in other sections of low spring and summer rainfall. Alfalfa with its deeply penetrating roots is able to draw moisture from a greater depth of soil than the more shallow-rooted grasses and clovers and will generally produce a larger yield of forage on the lighter soils and in areas of limited rainfall.

On certain soils in western Washington growers have not been successful in establishing satisfactory stands of alfalfa. While studying the importance of proper soil management and fertility in establishing stands, it was observed that the second, third, and fourth cuttings of alfalfa in a great number of fields showed severe yellowing, reddening, and dwarfing. Chemical analyses of the soil, pot culture studies, and field trials indicated that this condition, commonly referred to as "alfalfa yellows," could be corrected by the addition of boron and that striking increases in yield could be obtained when this deficiency was corrected. Similar results have been obtained in other parts of the Pacific Northwest.[1] As a result, a preliminary survey was made to determine the occurrence and importance of boron deficiency in alfalfa production in western Washington.

DISTRIBUTION

Surveys during the years 1937 to 1940, inclusive, showed that boron deficiency in alfalfa was widespread in western Washington and particularly severe in plantings on upland soils. Although some injury was observed on certain river-bottom soils, in most cases the deficiency did not appear to be serious. Only limited observations were made in Island, Clallam, and Jefferson counties, and none was made in San Juan, Wahkiakum, or Mason counties. Further survey may show the trouble to be more widespread. The areas where the deficiency has been observed are indicated in Table 2.

Little injury was noted in irrigated fields in Clallam county and in plantings of alfalfa on irrigated Puget sandy loam in Whatcom county.

SYMPTOMS AND EFFECTS

As shown in Color Plate I, the most conspicuous symptom of boron deficiency of alfalfa is the replacement of the green color of normal foliage with a yellowing, and in some cases, a reddening of leaves. Yellowing and reddening usually occur first on the upper leaves which may drop prematurely. A serious dwarfing of the plant occurs, with the distances between branches of affected plants much

[1] W. L. Powers, "Boron in Relaton to Soil Fertility in the Pacific Northwest," Proc. Soil Science Soc. Amer. 4:190-196. 1939.

Table 2. Observed Occurrence of Boron Deficiency on Alfalfa in Western Washington, 1937-1940, Inclusive

County	Location	Soil Series	Severity
Clallam	Observed in one field near Sequim	Carlsborg	Severe
Clark	Nearly all upland soils. On river-bottom plantinngs. Washougal, Vancouver	Felida, Lauren, Hesson, Olympic, Sifton, Sacramento, Columbia	Severe Severe Severe Moderate to severe
Cowlitz	Castlerock Woodland	Riverbottom (Puget) Olympic	Severe Moderate
Island	Prairie Center Smith's Prairie	Ebeys	Mild. No severe symptoms observed to date. Trial applications 1940
King	Bellevue Kent	Alderwood (Everett) Puget	Moderate Moderate
Lewis	Chehalis Valley	Newburg, Chehalis	Moderate
Pierce	Roy Puyallup	Alderwood (Everett) gravelly loam	Moderate Severe
Skagit	Skagit Flats	Puget	Moderate
Skamania	Carson Underwood	Wind River, Hillsboro, Underwood	Moderate Moderate
Klickitat	White Salmon	Underwood	Moderate
Snohomish	Snohomish	Melbourne	Mild
Whatcom	General over county	Lynden, Bellingham, Custer, Whatcom, Puget	Severe Severe Moderate to severe

shorter than on normal plants. Severely dwarfed and yellowed plants fail to form flowers. In fields where the deficiency is pronounced the growth is irregular with small areas of apparently normal plants scattered throughout the planting. In fields where the deficiency is slight, the reverse is true with small areas of yellowed and dwarfed plants scattered throughout the apparently healthy planting. On upland soils the disorder appears first on the knolls and slopes where it is generally more severe than in depressions or low areas in the same field.

The development of symptoms appears to be closely associated with the moisture supply in the soil. Although considerable injury was present on second cutting alfalfa in plantings on Felida silt loam in Clark county in 1939, no symptoms were observed in the second cut-

RECOMMENDATIONS FOR CONTROL OF ALFALFA YELLOWS CAUSED BY BORON DEFICIENCY

1. To fields in which boron deficiency symptoms as indicated in Plate I are present on alfalfa, borax (sodium borate) should be broadcast at the rate of 50 to 60 pounds per acre for silt and clay loam soils and at the rate of 30 to 40 pounds per acre for sandy loams and lighter soils. An application of 50 pounds of borax per acre at the present time costs approximately $1.50, exclusive of labor. Since the response to one application of boron will last for a period of three years or more the annual cost of boron amounts to approximately fifty cents per acre. When alfalfa hay has a value of $10.00 per ton an increased yield of only 100 pounds of hay annually is sufficient to pay for the materials used.

2. Applications should not be heavier than recommended since boron is definitely toxic to plants when used in large amounts.

3. Applications should be made preferably in the fall in non-irrigated sections of low spring rainfall such as Island County and before growth starts in the spring in other areas of western Washington.

4. Borax may be applied by hand or with fertilizer distributors after mixing with commercial fertilizers, soil, peat, or other bulking materials in order to get an even distribution. A modified wheelbarrow grass seeder may be used to apply the borax without mixing. This method or one using the cyclone type seeder appear to be the most satisfactory.

5. When deficiency symptoms reappear, make another application of borax or boric acid.

Plate 1. Boron deficient alfalfa on left, healthy plant on right; taken from plots in illustration below.

Plate 2. Boron deficiency in plot on left, corrected with an application of 40 pounds of borax per acre on right.

ings in the same plantings in 1940. As shown in Table 3, the rainfall for the spring and summer months was higher in 1940 than usual and it is likely that the more adequate supply of moisture prevented development of symptoms.

Table 3. Rainfall in Clark County, January 1 to August 1, 1939-1940*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
1939	4.89	4.66	2.23	0.39	1.39	1.69	0.77	16.02
1940	2.88	10.52	4.26	3.43	1.95	0.00	0.71	23.75

* U. S. Department of Commerce, Weather Bureau, Seattle, Washington.

The effects of moisture supply in the soil were also evident in experimental plots located on two soil types six miles apart in the same rainfall area of Clark county. Plot 1 was located on Felida silt loam which has a moisture-holding[1] capacity of 35 per cent. Plot 2 was located on Lauren sandy loam with a moisture-holding capacity of 15 per cent. No symptoms were observed on the second cutting on the heavier soil, while severe injury was evident fully a month earlier in the second cutting on the lighter soil. In Whatcom county only mild symptoms of boron deficiency were present on the plants in the irrigated portions of several fields on Puget sandy loam, while the alfalfa on the unirrigated portions of the same fields showed the typical yellowing, reddening, and dwarfing. In pot culture studies the appearance of symptoms was accelerated when the moisture supply was limited.

EXPERIMENTAL RESULTS

Pot Culture Studies with Alfalfa

Seven pound samples of Lauren sandy loam, taken from a field in which alfalfa was showing deficiency symptoms, were placed into shallow flats in the spring of 1938. The flats were treated in quadruplicate at follows: P+K, P+K+Ca, P+K+B, and P+K+Ca+B.[2] The flats were planted to Grimm alfalfa and following germination, were thinned to 20 plants per flat. Characteristic symptoms of boron deficiency developed in the second cutting of alfalfa made in the fall of 1938 and in the second and third cuttings in 1939 in all the flats except those to which boron had been added. Similar studies were conducted during 1939 and 1940 with Lauren sandy loam, Felida silt loam, and Alderwood gravelly sandy loam. Deficiency symptoms developed in all flats except those to which boron had been added and in every case the symptoms were more severe in the flats that had received lime in addition to phosphorus and potassium.

[1] Moisture held by surface soil 24 hours after heavy rain.

[2] P=Treble superphosphate; K=Potash (muriate); Ca=Lime (hydrated); B=Boron (sodium borate, $Na_2B_4O_7$). All materials of commercial grades.

Pot Culture Studies with Sunflower

In addition to alfalfa several other plants were used in an effort to find an indicator crop that could be used to determine rapidly the available boron supply in the soil. The sunflower, Helianthus sp., appears to be the most promising,[1] developing distinct and characteristic symptoms when grown on boron deficient soil. A pot culture experiment was set up in quadruplicate in which additions of a complete fertilizer were used as basic treatments. To one series, boron was added; to another lime, and to a third, both lime and boron. Five sunflower plants were grown in cans each containing from five to seven pounds of soil, depending on the volume weight of the soil. Lime was used in this experiment since it had been noted that the addition of this material accentuated the boron deficiency symptoms in alfalfa. The results of this experiment showed that the sunflower apparently demands comparatively large quantities of available boron in the soil for normal development, since deficiency symptoms appeared on plants in pot culture growing in soils which had shown no field symptoms of boron deficiency. On soils markedly deficient in boron, as determined by the presence of symptoms on alfalfa plants in the field, the deficiency symptoms on sunflowers in pot cultures appear a number of days earlier than on soils which have a more adequate supply of available boron. In some soils used in these studies, the boron supply was sufficient to prevent the appearance of deficiency symptoms on sunflower. Tests have indicated that when no symptoms appear on sunflowers in pot culture, none will appear in the field; and when the symptoms appear late in the period of growth of the sunflower, the boron supply may still be ample for the production of most field crops.

Experiments are in progress to correlate the available boron supply in the soil with the length of time required for development of deficiency symptoms on sun-flowers growing in pot culture.

Field Trials with Alfalfa

In order to determine crop response, proper rates and time of application, and duration of effects of treatments, applications of borax were made in the fall of 1938 to soils in which alfalfa was showing deficiency symptoms. On October 8, 1938, 10 pounds of borax were applied to an alfalfa field on Lauren sandy loam and 28 pounds per acre were added to a field on Felida silt loam in Clark county. On October 9, 1938, 25 pounds per acre were added to alfalfa plots on the shot clay upland soil on the experiment station farm at Puyallup.

In 1939 and 1940, deficiency symptoms did not appear on the first cuttings in either the treated or non-treated fields. There was little difference in the yield on the first cutting in the treated and non-

[1] C. E. Schuster and R. E. Stephenson, "Sunflower as an Indicator Plant of Boron Deficiency in Soils," Jour. Am. Soc. Agron. 32:607-621, 1940.

treated fields, indicating that if symptoms of boron deficiency are absent no marked increases in yield can be expected from applications of boron. This is illustrated by yields from the first cutting on the Bliss farm on Felida silt loam. The untreated portion of this field produced 14,440 pounds of green and 4,246 pounds of dry hay, while the yield from the treated plots was only slightly greater, 14,669 pounds green and 4,383 pounds of dry hay per acre. The second and third cuttings showed a marked improvement in growth and color in the treated areas, and, although the majority of the plants in the field appeared normal, it was evident that the applications had been too light since some dwarfed and yellowed plants were still present in treated areas. Similar responses were noted on the plots at Puyallup.

The response to the application of 10 pounds of borax on Lauren sandy loam made on October 8, 1938, was still evident in the second cutting made on June 20, 1940. At this cutting date the yield on the treated portion of the field was 2,791 pounds and on the untreated area,

Fig. 1. Response of second cutting of alfalfa, June 20, 1940, on Lauren sandy loam, Clark County, to 10 pounds of borax applied October 8, 1938. Photo by T. Marsh.

1,813 pounds of hay per acre (Fig. 1). No further growth occurred on the non-treated areas of this field, while a light third cutting was harvested on the treated areas, showing that the effects of even a small application of borax persisted for two years.

Since the lighter applications made in 1938 did not completely eliminate the deficiency symptoms, heavier rates of application were

used in the 1940 studies. The borax applications on the Felida and Lauren soils in Clark county were made with a modified wheelbarrow grass seeder on April 4, 1940. No symptoms of boron deficiency developed in the first or second cuttings, and, since previous work showed that little response could not be expected from applications of boron when no symptoms were evident, no harvest records were taken. At the time of the third cutting, however, deficiency symptons were severe on untreated areas, and striking increases in yield were obtained from both the 40- and 60-pound applications of borax (Fig. 2) The 40-pound applications failed to eliminate all symptoms of boron deficiency in the third cutting and a fourth cutting was not produced. The 60-pound application, on the other hand, eliminated all deficiency symptoms in the third cutting and yielded a fourth cutting of 6,446 pounds of green alfalfa per acre. Table 4 shows the yield of alfalfa obtained at the third cutting following applications of borax in Clark county in 1940.

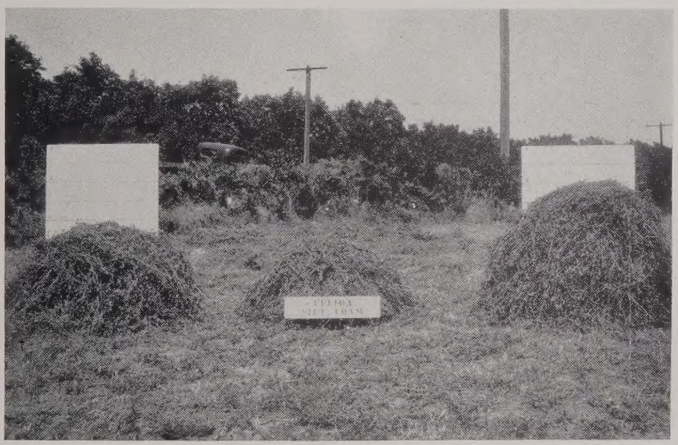

Fig. 2. Plot yield of third cutting of alfalfa on Felida silt loam (Wilbur Kenney farm), Clark County, from applications of 40 pounds (left), check (center), and 60 pounds (right) of borax per acre. Photo by T. Marsh.

Although the yields varied in the several fields because of different soil fertility and management practices, increases in yield were obtained on all plots to which borax had been added. The size or magnitude of the increases from boron applications were proportional to the severity of the deficiency. Very few yellowed plants, for example, were observed on the Dugan farm in planting No. I, while

Table 4. Yields of Third Cutting Alfalfa on Boron Plots on Felida Silt Loam, Clark County, 1940

Farm	Lbs. Borax per acre	Yield in lbs. per acre		Per cent increase in dry matter over check
		Green	Cured*	
Kennedy I	0	†3,070	1,519	——
	40	†4,319	2,178	43.3
	60	†6,925	2,908	91.4
Kennedy II	0	4,420	1,457	——
	40	6,327	2,665	82.9
	60	12,988	4,600	216.0
Woolf	0	6,838	2,200	——
	40	10,159	3,399	54.5
Bliss	0	3,298	——	——
	40	5,218	——	——
Dugan 1	0	3,343	——	——
	40	3,717	——	——
Dugan II	0	6,534	——	——
	40	8,322	——	——

*Calc. to 20% moisture.
†Partially air-dried.

symptoms were more severe in planting No. II. In the plantings on the Kennedy and Woolf farms deficiency symptoms were severe, while the symptoms on the Bliss farm were of moderate severity.

Field Trials with Alfalfa Using Farm Manure and Boron

Fall or spring applications of manure alone, although increasing alfalfa yields in all cases, did not bring about a complete disappearance of symptoms of boron deficiency. Poultry manure gave indications of being particularly low in available boron since the appearance of symptoms was accentuated in fields to which it had been added. Greater increases in yields from additions of boron were generally obtained from fields in a comparatively high state of fertility than from applications to poorer soils, and the addition of boron to manured fields on born deficient soils increased growth materially when compared to manure applications alone.

Weed Control from Boron Applications

Although no study was made of the specificity of boron in weed control, it was observed that plots treated with borax had fewer weeds than adjoining untreated plots (Fig. 1). This may have been the result of the development of stronger competition with the weeds by the more vigorous alfalfa growth on treated plots.

METHODS OF APPLICATION

Because only small amounts of borax are applied per acre, it should be mixed with fertilizers, sand, or other inert materials in order to obtain a more even distribution, or it may be applied with equipment such as the cyclone or the wheelbarrow grass seeders. A considerable amount of labor is involved in mixing the borax with other materials and applying the mixture to the soil in a uniform manner. With the grass seeders the borax may be applied directly without mixing. The use of the modified wheelbarrow grass seeder (Fig. 3)

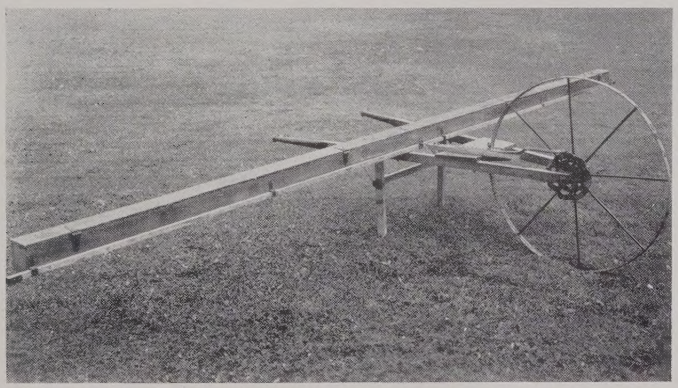

Fig. 3. Wheelbarrow grass seeder used to distribute borax. Photo by T. Marsh.

proved to be a satisfactory method of applying borax to alfalfa fields. In order to adapt the grass seeder for borax distribution, it was necessary to lengthen the stroke of the feed-chain in order to increase the flow of borax. This was accomplished by setting the seed box away from the wheel two inches from its original position. The metal strip which connects the rocker arm with the slide bar also was lengthened. With these adjustments the machine used delivered a maximum of approximately 25 pounds of borax per acre. Smaller quantities were applied by moving the eccentric peg so that the stroke of the feed-chain was shortened. For heavier applications it was found necessary to cover a field twice. It may be possible that further adjustments can be made to increase the rate of flow from the seeder and permit the application of 40 pounds per acre with one coverage. A large area can be covered in a short time since these seeders cover a strip 14 feet wide. Even distribution was obtained with this machine even in windy weather.

MATERIALS

Boric acid (17.49 per cent boron) or sodium borate (11.34 per cent boron) may be used as sources of boron. For field applications the sodium borate sold under the trade name "borax" is more satisfactory since it is usually cheaper and is free flowing, which makes it easier to apply. At present borax is priced at approximately $3.25 per hundred pounds of $2.50 per hundred pounds in ton lots.

SUMMARY

Surveys show that boron deficiency (Alfalfa Yellows) occurs in much of the 15,000 acres of alfalfa in western Washington. Soil types on which the deficiency was most commonly observed were mainly in upland areas.

Boron deficiency manifests itself as a yellowing and reddening of the leaves. The plants are severely dwarfed and rarely form flowers.

Pot culture studies and field trials showed that the deficiency may be corrected by applications of 50 to 60 pounds of borax (sodium borate) per acre to silt and clay loam soils and by 30 to 40 pounds on the lighter soils such as loams, sandy loams, and sands.

Work has shown that responses can be expected from either fall or spring applications, providing the material becomes dissolved and mixed with the soil.

Applications of barnyard manure alone did not make enough boron available to completely eliminate the deficiency. Poultry manure, while stimulating the growth of alfalfa, often accentuated the boron deficiency symptoms.

The borax may be applied after mixing with commercial fertilizer or inert materials such as sand or soil to increase the volume before application, or it may be applied directly without mixing through the use of a cyclone or a modified wheelbarrow grass seeder.